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NORMAL-INCIDENCE EXTREME ULTRAVIOLET GRATING SPECTROMETER.(U)
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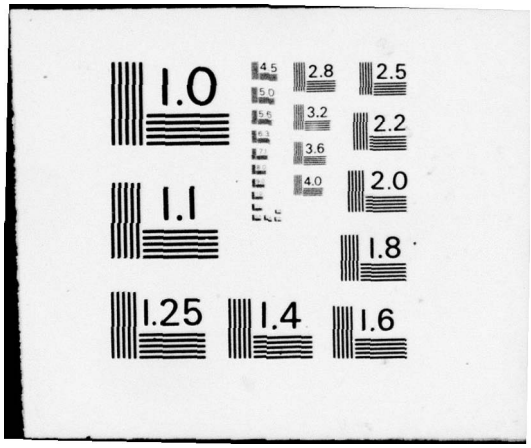
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AFGL-TR-76-0171

(12)

NORMAL-INCIDENCE EXTREME ULTRAVIOLET GRATING SPECTROMETER

Joseph P. Padur

Comstock & Wescott, Inc.
765 Concord Avenue
Cambridge, Massachusetts 02138

31 July 1976

Final Report for Period 1 September 1973 - 30 June 1976

Approved for public release; distribution unlimited

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

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REPORT DOCUMENTATION PAGE

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report describes the design, development, and fabrication of a normal-incidence ultraviolet grating spectrometer for sounding rockets and the field services supporting its launch.

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APPENDIX

1) Letter Report on Instrumentation and Flight of AFGL Experiment RS-61 dated 24 May 1976 (True Copy)

1. INTRODUCTION

This instrument was a near normal incidence spectrometer of an Ebert-Fastie configuration designed to monitor the solar spectrum in the range of wavelengths from 1700Å to 3500Å. It had the mechanical capability of continuous or single step coverage of the wavelength range from central image to 4000 Angstroms. For reference in the drawings, it is referred to as Model 5030A.

2. TECHNICAL DESCRIPTION

2.1 Instrument Package

The instrument was manufactured from a solid block of Brush I-220 beryllium. This is equivalent to Kawecki HP-21 which was utilized for a similar spectrometer under a previous contract. The selection of beryllium as the optimum material for this application was made because of the desirable combination of its physical characteristics; namely, high elastic modulus, high thermal conductivity, low coefficient of thermal expansion, low density, and dimensional stability.

During the machining of the beryllium billet at Precision Products, Inc. in North Haven, Connecticut, a major problem was encountered when a crack developed in the housing. Initial salvage steps (trepan of cracked area) were unsuccessful in eliminating continued crack growth. The services of Dr. B. L. Averbach, Professor of Metallurgy at M.I.T., were retained to assist in determining the cause (or causes) of the cracks and to recommend corrective steps to repair and salvage the housing.

Under the guidance of Professor Averbach, the defective sections were successfully removed from the housing at the machine shop site. New procedures and specifications were drawn up with special enumerated precautions to be followed for the continuation of the machining. A subsequent visit to Precision Products, Inc. revealed that no work had been undertaken by them for several

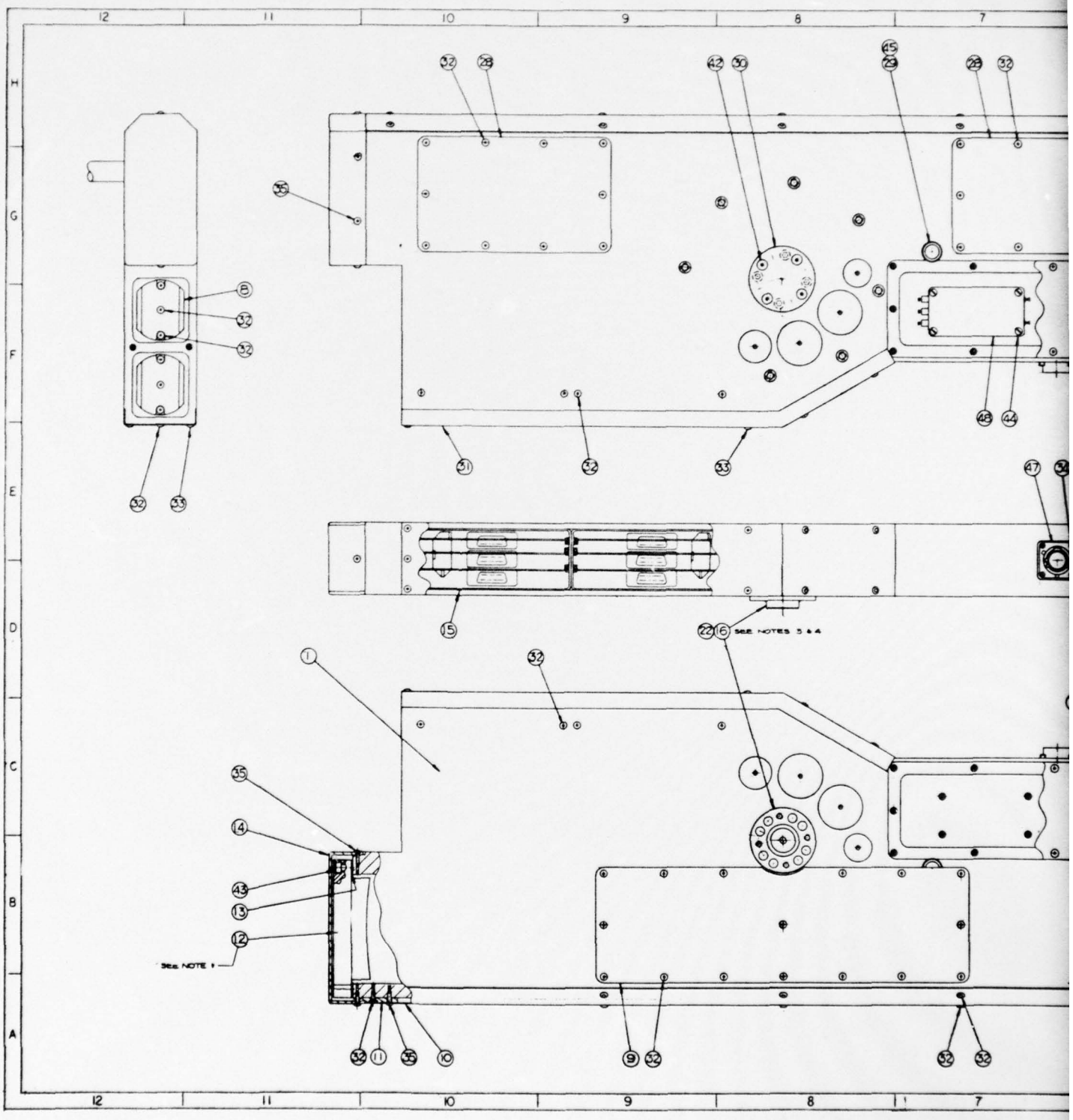
months. It was decided to cancel the order with them and issue a new order to Hardric Laboratories, Inc. of Waltham, Mass. Regular visits to this contractor to confirm the progress of work, coupled with the necessary inspections, resulted in an acceptably finished housing.

The main assembly drawing of the instrument, as designed, is shown in Figure 1, and a photograph of the assembled instrument is presented in Figure 2. A listing of the technical characteristics is included in Table I. The various components and their functions are discussed separately below.

2.2 Entrance Aperture

The entrance aperture consisted of an electroformed slit 76 microns wide by six millimeters high and had straight edges. It was mounted parallel to the exist aperture on the slit assembly shown in Figure 3.

A diffraction limit slit was used in conjunction with the entrance aperture to limit the numerical aperture to the breadth of the central maximum at 4000Å. Figure 4 illustrates the diffraction limit slit used in this instrument.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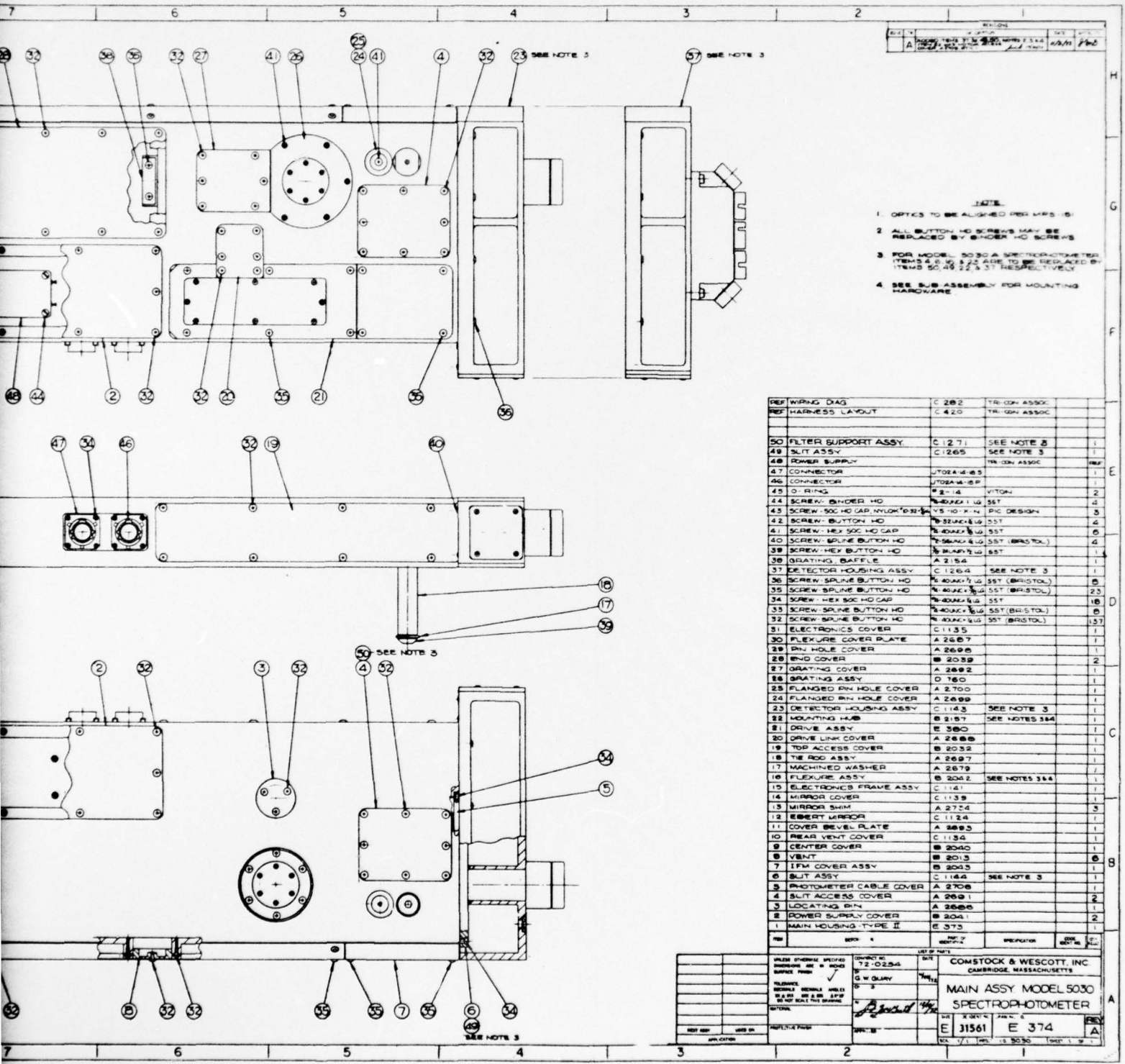
See NOTES 3 & 4
See NOTE 1



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REF	HARNESS LAYOUT	C 420	TRI-COM ASSOC		
50	FILTER SUPPORT ASSY	C 1271	SEE NOTE 3		1
49	SLIT ASSY	C 1265	SEE NOTE 3		1
48	POWER SUPPLY		TRI-COM ASSOC		REF
47	CONNECTOR	UT024-4-85			1
46	CONNECTOR	UT024-14-6P			1
45	O-RING	# 2-114	VITON		2
44	SCREW-BINDER HD	#6-32UNC-1/4 LG	SST		4
43	SCREW-SOC HD CAP, NYLOK	#5-40-K-N	PIC DESIGN		3
42	SCREW-BUTTON HD	#6-32UNC-3/16 LG	SST		4
41	SCREW-HEX SOC HD CAP	#6-40UNC-3/16 LG	SST		6
40	SCREW-SPLINE BUTTON HD	#6-32UNC-3/16 LG	SST (BRISTOL)		4
39	SCREW-HEX BUTTON HD	#6-32UNC-3/16 LG	SST		1
38	GRATING BAFFLE	A 2154			1
37	DETECTOR HOUSING ASSY	C 1264	SEE NOTE 3		1
36	SCREW-SPLINE BUTTON HD	#6-40UNC-1/2 LG	SST (BRISTOL)		5
35	SCREW-SPLINE BUTTON HD	#6-40UNC-5/16 LG	SST (BRISTOL)		23
34	SCREW-HEX SOC HD CAP	#6-40UNC-3/16	SST		18
33	SCREW-SPLINE BUTTON HD	#6-40UNC-3/16 LG	SST (BRISTOL)		5
32	SCREW-SPLINE BUTTON HD	#6-40UNC-3/16	SST (BRISTOL)		157
31	ELECTRONICS COVER	C 1135			1
30	FLEXURE COVER PLATE	A 2687			1
29	PIN HOLE COVER	A 2698			1
28	END COVER	B 2039			2
27	GRATING COVER	A 2692			1
26	GRATING ASSY	D 760			1
25	FLANGED PIN HOLE COVER	A 2700			1
24	FLANGED PIN HOLE COVER	A 2699			1
23	DETECTOR HOUSING ASSY	C 1143	SEE NOTE 3		1
22	MOUNTING HUB	B 2157	SEE NOTES 3&4		1
21	DRIVE ASSY	E 380			1
20	DRIVE LINK COVER	A 2688			1
19	TOP ACCESS COVER	B 2032			1
18	TIE ROD ASSY	A 2697			1
17	MACHINED WASHER	A 2679			1
16	FLEXURE ASSY	B 2042	SEE NOTES 3&4		1
15	ELECTRONICS FRAME ASSY	C 1141			1
14	MIRROR COVER	C 1139			1
13	MIRROR SHIM	A 2734			3
12	EBERT MIRROR	C 1124			1
11	COVER BEVEL PLATE	A 2693			1
10	REAR VENT COVER	C 1136			1
9	CENTER COVER	B 2040			1
8	VENT	B 2013			6
7	IFM COVER ASSY	B 2043			1
6	SLIT ASSY	C 1144	SEE NOTE 3		1
5	PHOTOMETER CABLE COVER	A 2708			1
4	SLIT ACCESS COVER	A 2691			2
3	LOCATING PIN	A 2686			1
2	POWER SUPPLY COVER	B 2041			2
1	MAIN HOUSING-TYPE II	E 373			1
ITEM	NOMEN.	PART OR IDENTIFYING NO.	SPECIFICATION		QTY REQ'D

COMSTOCK & WESCOTT, INC
CAMBRIDGE MASSACHUSETTS
MAIN ASSY MODEL 5030
SPECTROPHOTOMETER
E 31561 E 374 A

Figure 1. Main Assembly Model 5030 Spectrometer

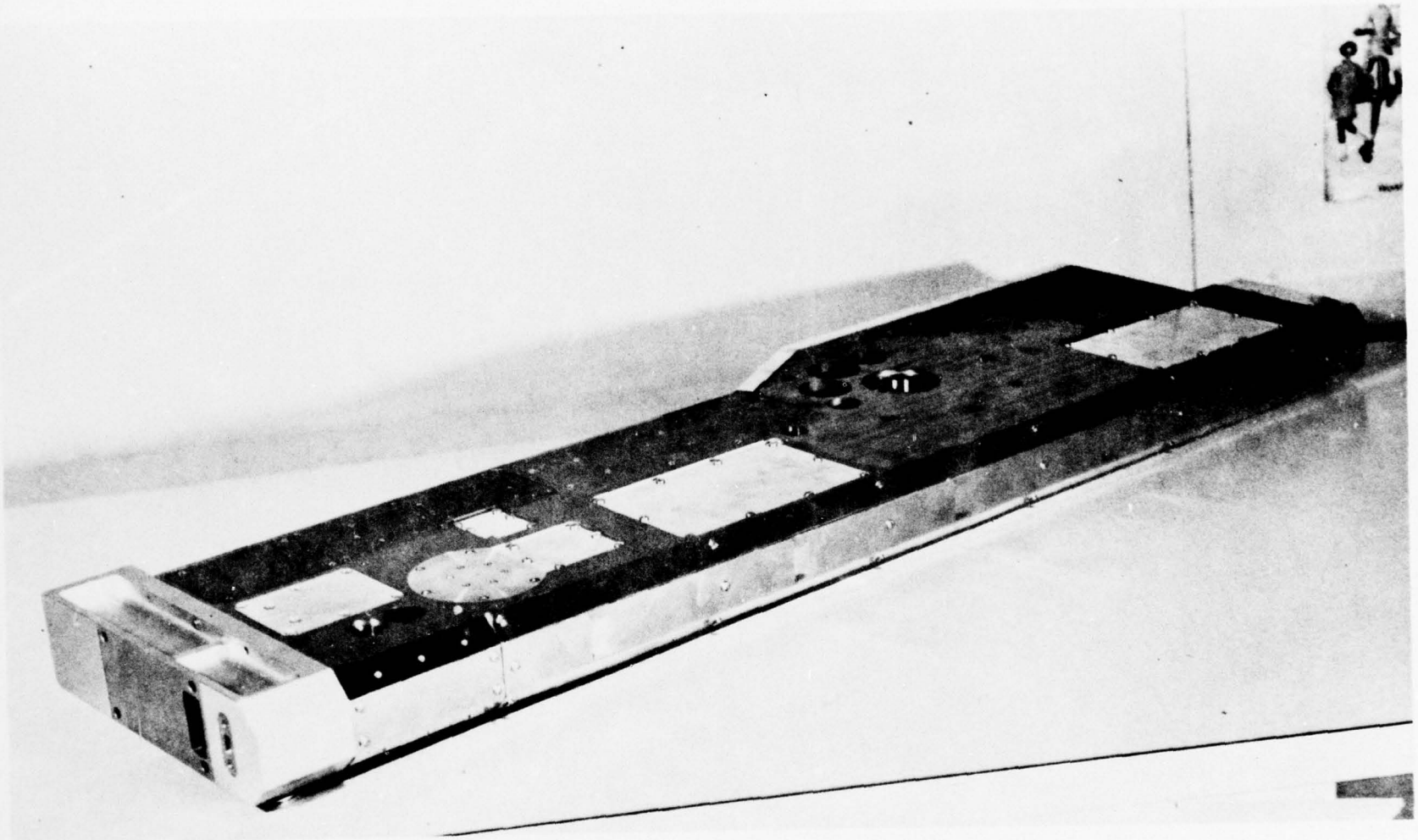


Figure 2. Assembled Model 5030 Spectrometer

TABLE I

Technical Characteristics of RS-61

Entrance Slit	.003" x 6 mm
Exit Slit	.003" x 6.4 mm
Grating	Bausch & Lomb #35-53-04-170, 3600 ℓ/mm
Detector	EMR 641F-06-18 S/N 19648
Wavelength	1700Å - 3500Å
Steps per Scan	23,400
Duration of Scan	105 sec
Stepping Rate	224 steps per sec
Nominal Step Increment	.077Å
Resolution	0.3Å FWHM
Filters	#7056 glass For background measurement @1900Å and 2400Å .01 Transmission Neutral Density for attenuation above 1944Å

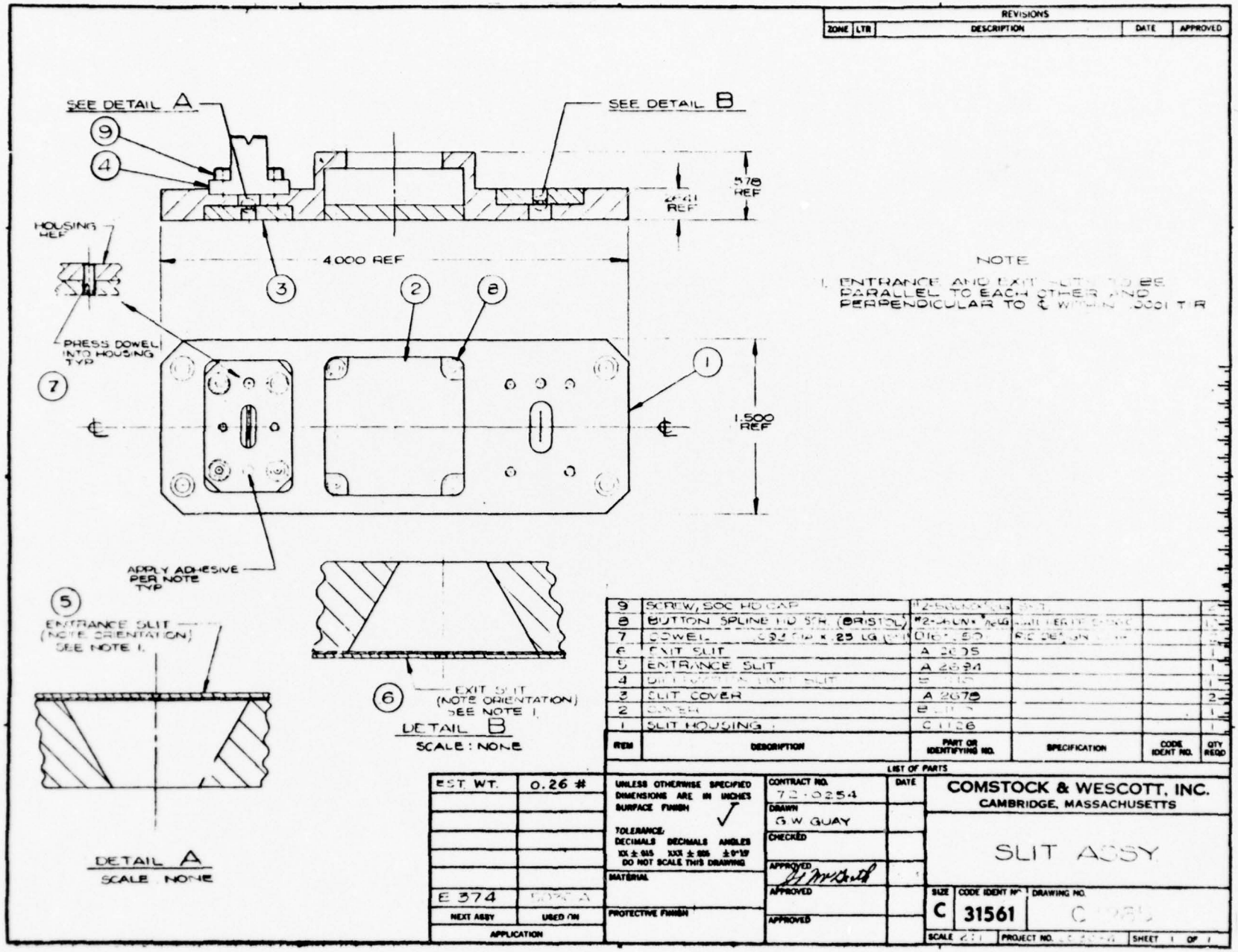


Figure 3. Slit Assembly

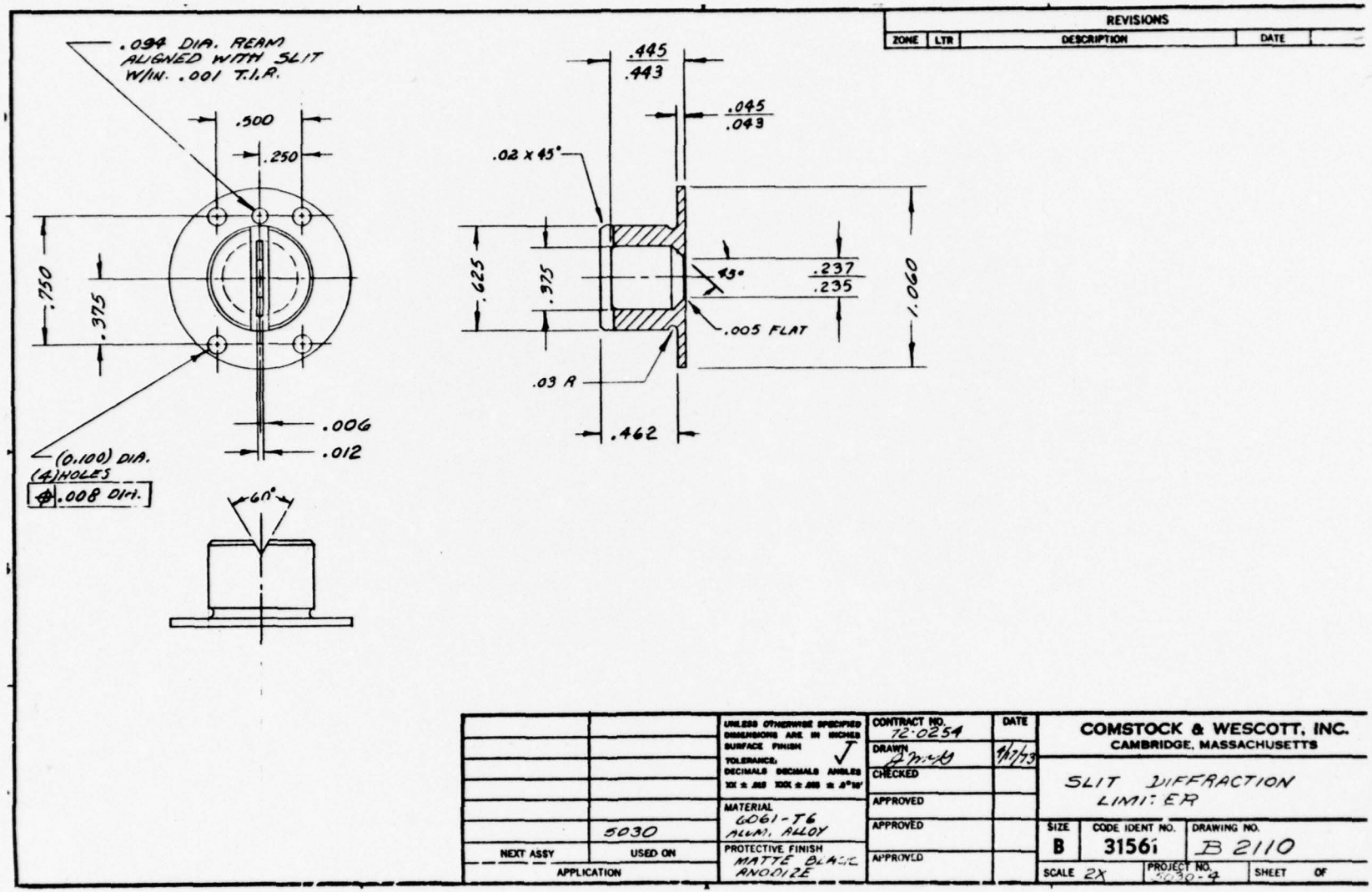


Figure 4. Slit Diffraction Limiter

2.3 Ebert Mirror

The collimating and focusing mirror for the spectrometer was fabricated from the same instrument-grade beryllium block as the housing and was figured to a spherical surface with a focal length of approximately 34 inches. After final machining, the blank was electroless nickel coated and then polished to the required figure and accuracy. After final polishing, the mirror was overcoated with aluminum (1000Å thick) and magnesium fluoride (250Å thick) by Acton Research Corporation, Acton, Mass. Reflectance measurements between 80% and 85% were obtained by them throughout the instrumental wavelength range.

Beryllium was chosen as the mirror material not only for the reasons it was chosen for the main instrument housing, but also because any dimensional changes caused by temperature variations of the instrument would automatically be compensated to maintain proper focusing. Figure 5 is the machining drawing for the mirror and illustrates the off-axis construction used in order to align the optical axis of the instrument parallel to the axial centerline of the instrument.

2.4 Grating Mount

The grating mount was manufactured from tool steel to a high degree of accuracy relative to the grating seat and other reference locating surfaces. Parallelism of the grating seat with the pivot shaft was maintained within 100 microinches. However, due to the non-perpendicularity of the grating rulings to the grating

base (discussion in 2.5), it was necessary to remachine the grating seat to correct this problem. A spring shim was used to preload the grating so that contact was maintained with the grating seat. The grating mount was assembled with ABEC-7 ball bearings in an appropriate housing. Grating mount rotation was accomplished through a ball and lever arm arrangement that was connected to the drive assembly drag link. The grating mount assembly is shown in Figure 6.

2.5 Grating

The diffraction grating was a standard plane reflection replica from Bausch & Lomb with 3600 lines per millimeter; Catalog No. 35-53-04-170. It had the following features:

Ruled Area (mm)	32 x 28
Blank Dimension (mm)	35 x 30
Grooves per mm	3600
Blaze Angle	25° 36'
Wavelength 1st Order (Littrow)	2400Å

During preliminary checks at AFGL, the output of the instrument was insensitive to long wavelengths (above 2800Å). Even at 2536Å the overall efficiency was down by at least a decade from that predicted. The overall alignment of the entrance slit, mirror, grating, and exit slit was remeasured at Comstock & Wescott and found to be intact at central image (as it was prior to delivery). A microscopic examination of the grating revealed that the rulings were not exactly perpendicular

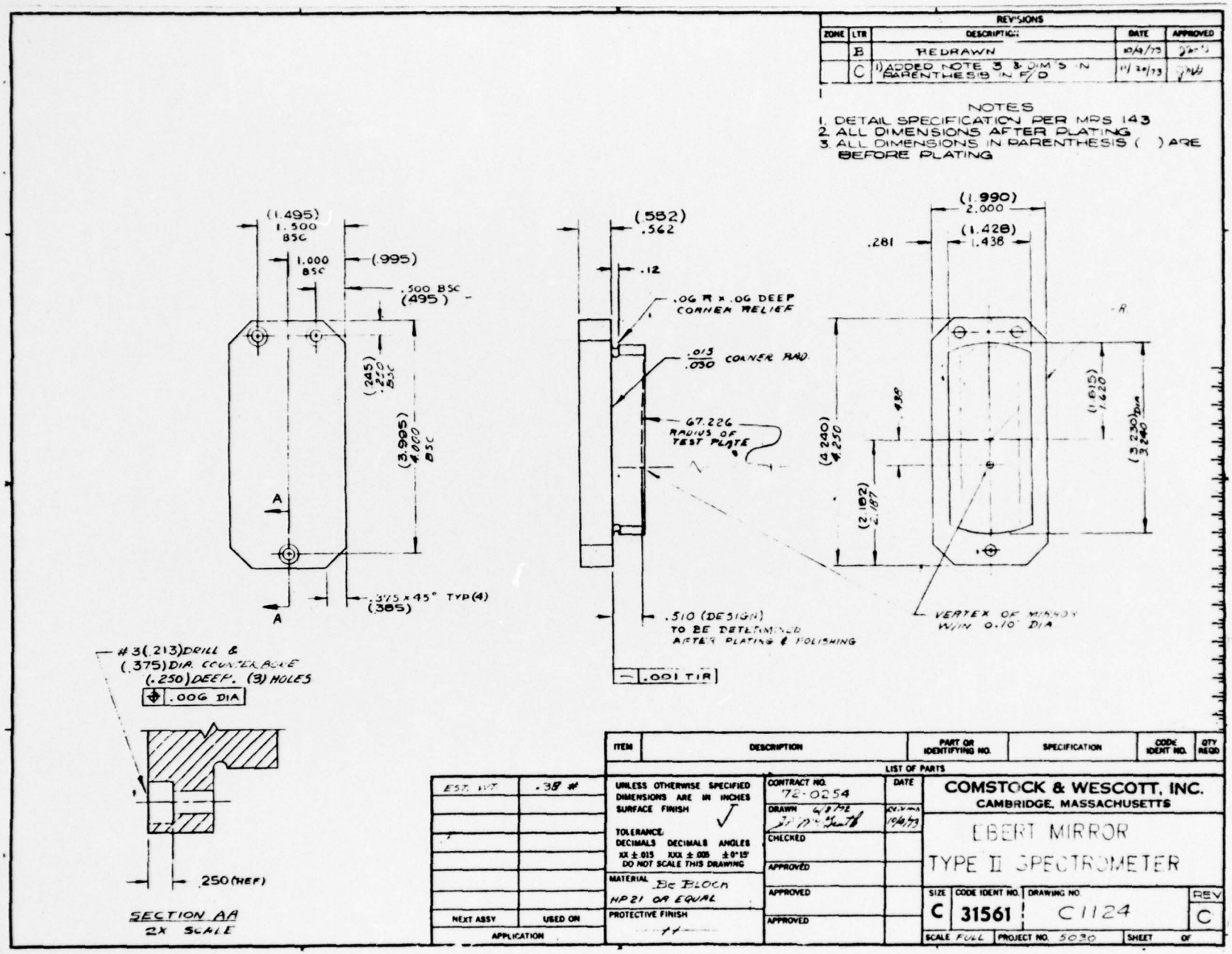
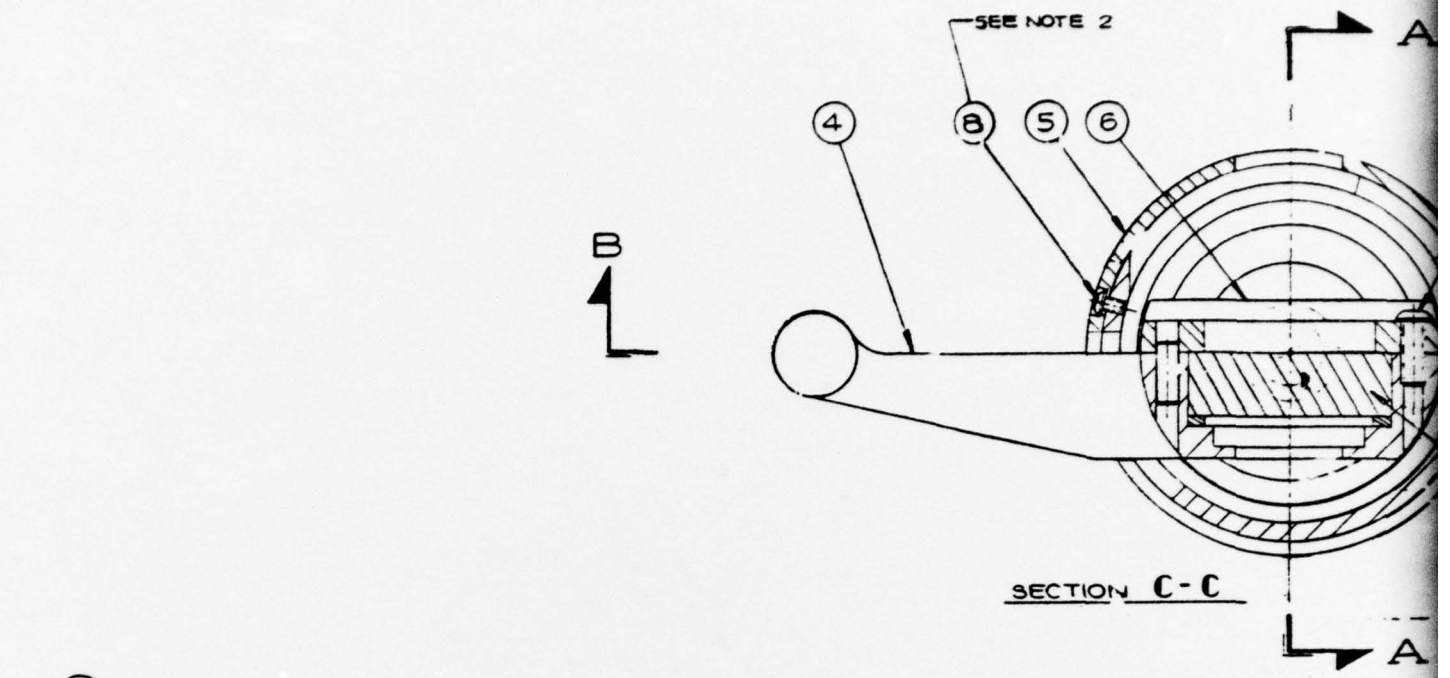


Figure 5. Ebert Mirror Type II Spectrometer



SECTION C-C

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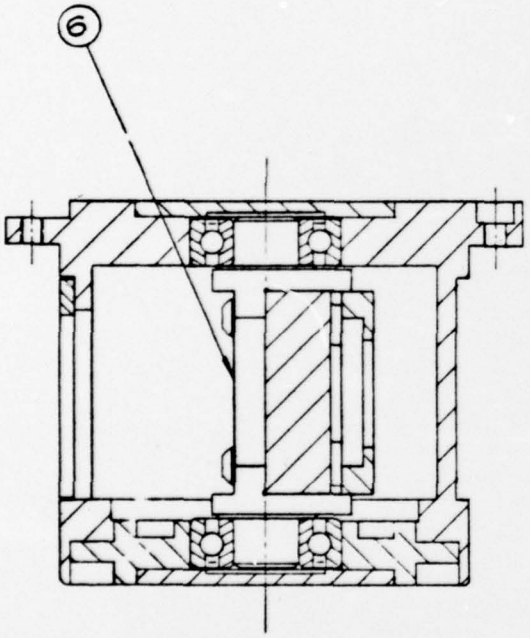
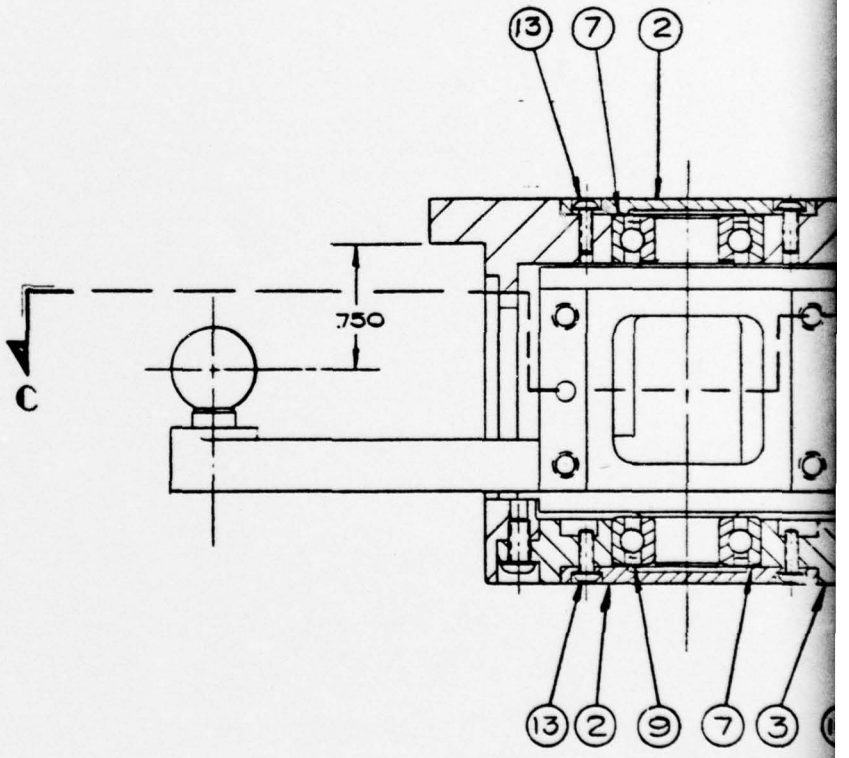


SECTION A-A



SECTION B-B

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REVISIONS				
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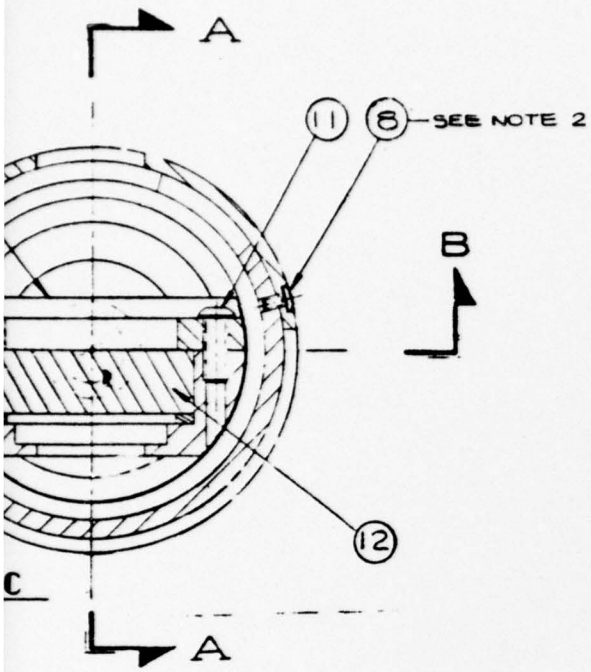
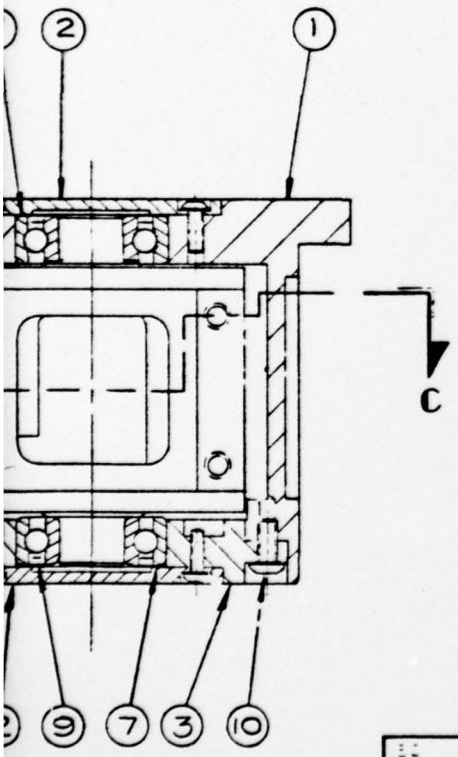


NOTES

1. SHIM LEVER ARM ASSY ITEM 4 TO DIMENSION SHOWN USING ITEM 7 TO OBTAIN PROPER DIMENSION AS WELL AS ZERO SHAKE IN BEARINGS.

2. MAY BE MADE FROM ITEM 13



SECTION B-B

ITE**	DESCRIPTION	PART OR IDENTIFYING NO.	SPECIFICATION	CODE IDENT NO.	QTY REQD
13	SCREW-SPLINE BUTTON HD.	#2-56 x 1/4 LG	SST (BRISTOL)		12
12	GRATING - 3600 L/MM	35-53-04-160	BAUSH & LOMB		1
11	SCREW-SPLINE BUTTON HD.	#4-40 x 3/8 LG	SST (BRISTOL)		4
10	SCREW-SPLINE BUTTON HD.	#4-40 x 5/16 LG	SST (BRISTOL)		6
9	BEARING	SR6PDK 5S	NEW HAMPSHIRE		2
8	SCREW-SPLINE BUTTON HD.	#2-56 x 1/8 LG	SST (BRISTOL)		3
7	SHIM .003 THK.	B3-51	PIC DESIGN CORP		AS REQD
6	GRATING MOUNT PIVOT	C 1130			1
5	RADIATION SHIELD	C 1128			1
4	LEVER ARM ASSY.	B 2045			
3	LOWER BEARING PLATE	C 1131			
2	BEARING COVER PLATE	B 2012			2
1	GRATING MOUNT HOUSING	D 756			1

LIST OF PARTS

E 374	
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
SURFACE FINISH ✓
TOLERANCE
DECIMALS XX ± .015 XXX ± .005 ANGLES ± 0.1°
DO NOT SCALE THIS DRAWING
MATERIAL
PROTECTIVE FINISH

		DATE
CONTRACT NO.	72-0254	
DRAWN	G.W. GUAY	11/7/72
CHECKED		
APPROVED		
APPROVED		
APPROVED		

COMSTOCK & WESCOTT, INC.
CAMBRIDGE, MASSACHUSETTS

GRATING ASSEMBLY
TYPE II

SIZE	CODE IDENT NO.	DRAWING NO.
D	31561	D 760

SCALE 2/1 | PROJECT NO 5030-1 | SHEET 2F

Figure 6. Grating Assembly Type II

to the grating seat (which itself was measured and found to be flat). Measurements showed that the rulings were approximately twelve (12) minutes off from true perpendicularity from the top to the base of the grating. The grating seat was machined to accommodate this grating in order to achieve true perpendicularity. Alignment checks were repeated on the entire instrument at central image and at 4050Å where a violet line from the mercury discharge could be observed. In both instances the resultant output spectrum could be viewed in focus at the exit slit and passing through it. The instrument was reassembled and delivered to AFGL for further tests and calibration. Efficiency measurements at that time were considerably improved to within a factor of two of that predicted.

2.6 Exit Aperture

The exit aperture was essentially identical to the entrance aperture, as described in Section 2.2, except the exit slit height was 6.4 mm.

2.7 Detector

The detector utilized in this instrument was an EMR 641F-06-18 photomultiplier. It had a fused silica window and a cesium telluride photocathode resulting in a detectable wavelength range of 1700 to 3500 Angstroms. The detector was operated as a photon counter and had a well-defined counting plateau when exposed to a constant source of ultraviolet radiation. It also had a low background count rate (less than

one count per second) when operated in the plateau region without illumination.

2.8 Drive Assembly

The drive assembly was designed according to the principle of the sine drive mechanism* and provided linear wavelength scanning over the range of wavelengths from central image to 3500Å. It consisted of a 28 volt dc permanent magnet stepper motor and gearhead, a 40 thread per inch drive screw, a linearly driven drag link with socket for accepting the grating lever arm ball, and limit switches.

The drive motor could be single-stepped for laboratory calibration or stepped during flight at the frequency of 224 steps per second to cover the proposed flight range of wavelength from 1700Å to 3500Å in 105 seconds. Provisions were made for mounting adjustable range limit switches to accommodate various scan modes. These were adjusted for laboratory and field checks which required longer scans (central image to 3500Å). The flight limits were set approximately at 1700Å and 3400Å.

2.9 Calibration Fixtures

No new calibration fixtures were necessary for this instrument. It was designed to incorporate existing fixtures at AFGL which were provided under a previous contract.

---

* R. M. Badger, et al, Rev. Sci. Inst. 19, 861 (1948)

2.10 Filters

2.10.1 Background Filter

A Corning No. 7056 borosilicate glass filter was utilized for in-flight background measurements at 1900Å and 2400Å. At these wavelengths the filter does not transmit, so any resultant signal would be from radiation above 2600Å (i.e. scattered light). At these two positions, when scanning toward longer wavelengths, the motor drive would stop, the filter would be inserted into the optical path, and background data would be accumulated for one second. The filter would then be withdrawn and the motor drive would continue scanning.

2.10.2 Neutral Density Filter

Due to the several orders of magnitude variation of the solar flux from 1700Å to 3500Å and to the count rate limitation of the detector-amplifier assembly, good quantitative values over the entire range would not be obtained. To retain adequate counting statistics at the short wavelength meant saturation of the detector-amplifier at the longer wavelengths. To compromise, a nominal one percent transmission neutral density filter to reduce the high count rate was installed in front of the entrance slit for wavelengths above 1944Å. Below this wavelength the filter was "powered out"

of the optical path. Even with this filter, count rates near saturation were obtained during the flight at some wavelength intervals.

2.11 Auxiliary Experiment

A Government-owned electron energy analyzer was integrated with the Ebert-Fastie spectrometer. It was calibrated independently from the spectrometer and added on for eye-block integration and launch.

3. FIELD SUPPORT SERVICES

3.1 Introduction

Engineering services were provided to support the preparation and launch of this ultraviolet spectrometer as a scientific payload on a sounding rocket. This work included:

1) The integration of the spectrometer with electronic assemblies, solar pointing control, and telemetry system provided under separate Government contracts.

2) The maintenance and operation of a Government-owned portable vacuum system for pre-flight preparation of the scientific payload.

3.2 Integration and Launch

This instrument was integrated at Ball Brothers Research Corporation in Boulder, Colorado, during the week of 26 April to 30 April 1976. It was launched aboard an Aerobee-150 rocket from White Sands Missile Range, New Mexico, on 18 May 1976. The details of the flight are covered in a letter report dated 24 May 1976 which is included in the Appendix.

A P P E N D I X

TRUE COPY

LETTER REPORT ON
INSTRUMENTATION AND FLIGHT OF
AFGL EXPERIMENT RS-61

Dated 24 May 1976

24 May 1976

LETTER REPORT ON
INSTRUMENTATION AND FLIGHT OF

AFGL Experiment	RS-61
Vehicle No.	A03.410-1
Launch Date	18 May 1976
Time:	1100 MDT
Site	White Sands Missile Range, New Mexico

Contract No. F19628-74-C-0002
Date of Report: 24 May 1976

Author: /s/
Joseph P. Padur, Project Physicist

Approved by: /s/
C. Fredric Young, Vice President

Prepared for

Air Force Geophysics Laboratory (AFGL)
Hanscom Air Force Base, Mass. 01731

This report is intended only for the internal management use of the contractor and the Air Force (AFGL).

COMSTOCK &
WESCOTT, INC.

Concord Avenue, Cambridge, Mass. 02138 Tel. 617 [illegible]
Research & Engineering for Product and Process Development
Since 1912

24 May 1976

Air Force Geophysics Laboratory
Department of the Air Force
Hanscom Air Force Base, Mass. 01731

Attention: Mr. Charles W. Chagnon (LKO)
Aeronomy Laboratory

Subject: Letter Report on Experimental Launch of Rocket Spectrometer No. 61 from White Sands Missile Range, New Mexico, on 18 May 1976.

Gentlemen:

The launching and flight of Rocket Spectrometer No. 61 were accomplished on 18 May 1976 in accordance with AFSC Management Report dated 6 April 1976.

Instrument

RS-61 is a near normal incidence spectrometer of an Ebert-Fastie configuration manufactured from a solid block of beryllium. It contains an EMR 641F photomultiplier with a fused silica window covering the desired wavelength range of 1700Å to 3400Å. The plane grating is a B&L 3600 ℓ/mm (Cat. No. 35-53-04-170) with a blaze angle of 25° 36'. The entrance and exit slits are both .003" wide. A borosilicate glass filter is inserted at 1900Å and 2400Å for background measurements. A nominal one percent transmission neutral density filter is used for count rate reduction above 1944Å. The resolution of the instrument is at least 0.3Å FWHM. Mounted to the beryllium housing is a Government furnished electron spectrometer as a "Piggy-back" experiment.

Integration

This instrument was integrated with its Solar Pointing Control (SPC-329-IIIA) and Telemetry System (TEL-348-VII) during the week of 26 April to 30 April 1976 at Ball Brothers Research Corporation, Boulder, Colorado. Vacuum checks were carried out on the cylindrical nose cone and F-section utilizing the helium leak detector to pin point measurable

leaks. After correction by Ball Brothers Research Corporation personnel, a final check was made ensuring a good vacuum seal.

Launch

The pumping system was unpacked, set up and checked out in N-200 at White Sands Missile Range in New Mexico. The entire system was helium leak checked and found to be operational. A vacuum recheck of the nose cone and F-section without the flight instrument was then carried out. They were both free of leaks and returned to Ball Brothers Research Corporation personnel for vehicle assembly.

Horizontal checks were carried out in N-200 on 14 May and a vertical check was accomplished in B-Tower on 17 May. The instrument was launched aboard an Aerobee-150 rocket from the B-Tower at LC-35 at 1100 MDT. Data were obtained from the normal incidence instrument as well as the electron spectrometer. The entire payload was successfully recovered after a few hours and preliminary checks with the respective GSE's indicate that both instruments seem to be in good condition.

Pre-Launch Pumpdown

17 May 1976

1910 Roughing on Payload

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1920	2.1×10^{-6} Torr	5μ	130μ
1930	8.8×10^{-7}	0μ	95μ
1945	6.2×10^{-7}	0μ	70μ
	Opened Gate Valve		
1950	4.0×10^{-4}	18μ	
2030	9.8×10^{-5}	5μ	
2130	5.8×10^{-5}	2μ	
2230	4.0×10^{-5}	1μ	
2330	3.2×10^{-5}	0μ	

AFGL - 3 -

17 May 1976

	Hi Vac Side	Foreline(T-1)	Nose Cone Side(T-2)
0030	3.0×10^{-5}	0	
0130	2.5×10^{-5}	0	
0230	2.3×10^{-5}	0	
0330	2.1×10^{-5}	0	
0430	1.8×10^{-5}	0	
0530	1.6×10^{-5}	0	
0630	1.5×10^{-5}	0	
0800	1.4×10^{-5}	0	
0900	1.4×10^{-5}	0	Secured Tower for Launch
0950	Rechecked Tower and Filled LN_2 Trap		

@ T-30 sec. Closed gate valve, back filled with N_2

@ T-18 sec. Retracted vacuum system from nose cone.

Very truly yours,

Joseph P. Padur
Project Physicist

JPP:ac